

METHODS OF SAMPLING AND TESTING
MT 101-04
MAKING AND CURING CONCRETE COMPRESSIVE AND
FLEXURAL STRENGTH TEST SPECIMENS
IN THE FIELD
(Modified AASHTO T23 and M205)

1 Scope:

- 1.1 This method covers procedures for making and curing cylindrical and prismatic specimens using job concrete that can be consolidated by rodding or vibration as described herein.
- 1.2 The concrete used to make the molded specimens shall have the same level of slump, air content, and percentage of coarse aggregate as the concrete being placed in the work.
- 1.3 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents given in the standard may be approximate.
- 1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:**2.1 AASHTO:**

M 205 Molds for Forming Concrete Test Cylinders Vertically
 T 23 Making and Curing Concrete Test Specimens in the Field
 T 141 Sampling Freshly Mixed Concrete

MT Materials Manual:

MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
 MT-104 Slump of Portland Cement Concrete
 MT-105 Sampling Fresh Concrete
 MT-107 Air Content of Freshly Mixed Concrete by the Volumetric Method
 MT-510 Field Numbering Concrete Cylinders

3 Apparatus:

- 3.1 *Molds, General*--Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under conditions of severe use. Molds shall be watertight during use as judged by their ability to hold water poured into them. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Molds shall be lightly coated with mineral oil or a suitable reactive form release material before use.

Note 1 -Single use molds (plastic, cardboard, tin) are not acceptable for use to cast concrete cylinders for acceptance samples. Single use molds are permitted for field cured cylinders used to determine false work removal, opening to traffic, etc.

- 3.2 *Reusable Vertical Molds*--Molds shall be constructed in the form of right circular cylinders which stand with the cylindrical axis vertical and the top open to receive the concrete. They shall have a nominal inside height equal to twice the nominal inside diameter. The average diameter of a mold shall not differ from the nominal diameter by more than 1 percent and no individual diameter shall differ from any other diameter by more than 2 percent. The plane of the rim of the mold and the

3 Apparatus: (continued)

bottom shall be perpendicular to the axis of the mold within 0.5 degrees (approximately equivalent to 1/8 in. in 12 in. or 3 mm. in 305 mm.). The molds must be provided with a closure or base on the lower end at right angles at the axis of the cylinder. The base will consist of a separate base plate and a means of attaching it to the cylindrical side walls. In preparation for use, the assembled mold and base plate shall be coated with a material that will prevent adherence to the concrete.

3.3 Beam Molds--Beam molds shall be rectangular in shape and or the dimensions required to produce the specimens stipulated in Section 4.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 1/8 in. (3.2 mm) for molds with depth or breadth of 6 in. (152 mm) or more. Molds shall produce specimens not more than 1/16 in. (1.6 mm) shorter than the required length in accordance with Section 4.2, but may exceed it by more than that amount.

3.4 Tamping Rods--Two sizes are specified in Table 1. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

Table 1 – Tamping Rod Requirements

Diameter of Cylinder or Width of Beam, In. (mm)	Rod Dimensions*	
	Diameter, in. (mm)	Length of Rod, in. (mm)
<6 (150)	3/8 (10)	12 (300)
6 (150)	5/8 (16)	20 (500)
9 (225)	5/8 (16)	26 (650)

*Rod tolerances length ± 4 in. (100 mm) and diameter $\pm 1/16$ in (2 mm).

3.4.1 Large Rod--5/8 in. (16 mm) in diameter and approximately 24 in. (610 mm) long.

3.4.2 Small Rod--3/8 in. (10 mm) in diameter and approximately 12 in. (305 mm) long.

3.5 Vibrators--Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The diameter of a round vibrator shall be no more than one-fourth the diameter of the cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. (76 mm).

3.6 Mallet--A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg) shall be used.

3.7 Small Tools--Tools and items which may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gage, scoops, and rules.

3.8 Slump Apparatus--The apparatus for measurement of slump shall conform to the requirements of Method MT-104.

3.9 Sampling and Mixing Receptacle--The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean, nonabsorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

3.10 Air Content Apparatus--The apparatus for measuring air content shall conform to the requirements of Methods MT-107 or MT-102.

4 Test Specimens:

- 4.1** *Compressive Strength Specimens*--Compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position, with a length equal to twice the diameter. The standard specimen shall be the 6 by 12 in. (150 by 300 mm) cylinder when the maximum size of the coarse aggregate does not exceed 2 in. (50 mm), either the concrete sample shall be treated by wet sieving as described in AASHTO T 141 or the diameter of the cylinder shall be at least three times the nominal maximum size of the coarse aggregate in the mixture. The specimens may be 4 by 8 in. (100 by 200 mm) cylinders when the nominal maximum size of the coarse aggregate does not exceed 1 in. (25 mm).
- 4.2** *Flexural Strength Specimens*--Flexural strength specimens shall be rectangular beams of concrete cast and hardened with long axes horizontal. The length shall be at least 2 in. (50 mm) greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. (152 by 152 mm) in cross section, and shall be used for concrete with a nominal maximum size coarse aggregate up to 2 in. (50 mm). When the nominal maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by the project specifications, beams made in the field shall not have a width or depth of less than 6 in.

5 Sampling Concrete:

- 5.1** The samples used to fabricate test specimens under this standard shall be obtained in accordance with Method MT-105 unless an alternative procedure has been approved.
- 5.2** Record the identity of the sample with respect to the location of the concrete represented and the time of casting.

6 Slump, Air Content, and Temperature:

- 6.1** *Slump*--Measure the slump of each batch of concrete, from which specimens are made, immediately after remixing in the receptacle as required in Method MT-104.
- 6.2** *Air Content*--Determine the air content in accordance with either Method MT-102 or Method MT-107. The concrete used in performing the air content test shall not be used in fabricating test specimens.

7 Molding Specimens:

- 7.1** *Place of Molding*--Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.
- 7.2** *Placing the Concrete*--Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop, trowel, or shovel around the perimeter of the mold opening when adding concrete to ensure an even distribution of the concrete and to minimize segregation. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after compaction. Do not add non-representative concrete to an under filled mold.
- 7.2.1** *Number of Layers*--Make specimens in layers as indicated in Tables 2 or 3.

Table 2 – Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
<i>Cylinders:</i>		
Diameter in. (mm)		
4 (100)	2	25
6 (150)	3	25
9 (225)	4	50
<i>Beams:</i>		
Width in. (mm)		
6 (150 to 8 (200)	2	Sec 7.3.2
>8 (over 200)	3 or more equal depths, each not to exceed 6 in. (150 mm)	Sec 7.3.2

Table 3 – Molding Requirements by Vibration

Specimen Type and Size	Number of layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, in. (mm)
<i>Cylinders:</i>			
Diameter, in. (mm)			
4 (100)	2	1	one-half depth of specimen
5 (150)	2	2	one-half depth of specimen
9 (225)	2	4	one-half depth of specimen
<i>Beams:</i>			
Width in. (mm)			
6 (150 to 8 (200)	1	Sec 7.4.2	depth of specimen 8 (200) as near as practicable
over 8 (200)	2 or more	Sec 7.4.2	depth of specimen 8 (200) as near as practicable

7.2.2 Select the proper tamping rod from section 3.4 and Table 1 or the proper vibrator from Section 3.5. If the method of consolidation is rodding, determine the molding requirements from Table 2. If the method if consolidation is vibration, determine the molding requirements from Table 3.

7.3 *Consolidation:*

7.3.1 *Methods of Consolidation*--Preparation of satisfactory specimens requires different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. Rod concrete with a slump greater than 3 in. (75 mm). Rod or vibrate concretes with slump of 1 to 3 in. (25 to 75 mm). Vibrate concretes with slump of less than 1 in. (25 mm).

7.3.2 *Rodding*--Place the concrete in the mold, in the required number of layers of approximately equal volume. For cylinders, rod each layer with the rounded end of the rod using the number of strokes specified in Table 2. The number of roddings per layer required for beams is one for each 2 in.² (13 cm²) top surface area of the specimen. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to

7.3 Consolidation: (continued)

penetrate about ½ in. (12 mm) into the underlying layer when the depth of the layer is less than 4 in. (100 mm), and about 1 in. (25 mm) when the depth is 4 in. or more. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Tap light-gage single-use molds, susceptible to damage if tapped with the mallet, using an open hand. After tapping, spade the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

7.3.3 *Vibration*--Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth. Continue vibration only long enough to achieve proper consolidation of the concrete. Over-vibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than 1/4 in. (6 mm). Finish the surface either during or after vibration where external vibration is used. Finish the surface after vibration when internal vibration is used. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about 1/8 in. (3 mm). Work it into the surface and then strike it off.

7.3.3.1 *Internal Vibration*--The diameter of the vibrating element, or thickness of a square vibrating element, shall be in accordance with the requirements of Section 3.5. For beams, the vibrating element shall not exceed _ of the width of the mold. For cylinders, the ratio of the diameter of the cylinder to the diameter of the vibrating element shall be 4.0 or higher. In compacting the specimen, the vibrator shall not be allowed to rest on the bottom or sides of the mold. Carefully withdraw the vibrator in such a manner that no air pockets are left in the specimen.

7.3.3.2 *Cylinders*--Use three insertions of the vibrator at different points for each layer. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single use molds that are susceptible to damage if tapped with a mallet.

7.3.3.3 *Beam*--Insert the vibrator at intervals not exceeding 6 in. (150 mm) along the centerline of the long dimension of the specimen. For specimens wider than 6 in., use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped.

7.3.4 *External Vibration*--When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

7.4 *Finishing*--After consolidation, unless the finishing has been performed during the vibration (7.3.3), strike off the surface of the concrete and flat or trowel it as required. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the molds and that has no depressions or projections larger than 1/8 in. (3mm).

7.4.1 *Cylinders*--After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a wood float or trowel.

7.4.2 *Beams*--After consolidation of the concrete, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.

7 Molding Specimens: (continued)

- 7.5 *Initial Storage*--Immediately after being struck off, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period. If specimens made in single use mold are moved, lift and support the specimens from the bottom of the molds with a large trowel or similar device.

8 Curing:

- 8.1 *COVERING AFTER FINISHING* - To prevent evaporation of water from the unhardened concrete, the specimens shall be covered immediately after finishing, preferably with a non-absorptive, non-reactive plate or a sheet of tough, durable, impervious plastic.
- 8.2 *Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance or Quality Control.*
- 8.3 *INITIAL CURING* – After molding, the specimens shall be stored in a temperature range between 60° to 80°F (16° to 27°C), and in a moist environment preventing any loss of moisture up to 48 hours (Note 2). At all times the temperature in and between specimens shall be controlled by shielding from direct rays of the sun and radiant heating devices. Specimens that are to be transported to the laboratory for standard curing (Section 9.2.1) before 48 hours shall remain in the molds in a moist environment, until they are received in the laboratory, de-molded and placed in standard curing. If specimens are not transported within 48 hours, the mold shall be removed within 24 ± 8 hours and standard curing used until transported. See section 10.1).

Note 2 - It may be necessary to create an environment during initial curing to provide satisfactory moisture and to control the temperature. The specimens may be immersed immediately in saturated limewater, and/or stored in tightly constructed wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap, or in heavyweight closed plastic bags. Immersing in saturated limewater is not acceptable for specimens in cardboard or other molds that expand when immersed in water. Other suitable methods may be used provided the foregoing requirements limiting specimen temperature and moisture loss are met. The temperature may be controlled by ventilation, or thermostatically controlled cooling devices, or by heating devices such as stoves, light bulbs, or thermostatically controlled heating elements. Temperature record of the specimens may be established by means of maximum-minimum thermometers. Early age results may be lower when stored near 60°F (16°C) and higher when stored near 80°F (27°C).

8.4 STANDARD CURING:

- 8.4.1 *Cylinders* – Upon completion of initial curing and within 30 minutes after removing the molds, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of $73.4 \pm 3^\circ\text{F}$ ($23 \pm 1.7^\circ\text{C}$). Temperatures between 68° and 86°F (20° and 30°C) are permitted for a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times, except when capping with sulfur mortar capping compound. When capping with this material, the ends of the cylinder will be dried as described in AASHTO T 231. Specimens shall not be exposed to dripping or running water. The required moist storage can be obtained by immersion in saturated limewater and may be obtained by storage in a moist room or cabinet meeting the requirements of AASHTO M 201.
- 8.4.2 *Beams* – Beams are to be cured the same as cylinders (Section 10.1) except for a minimum of 20 hours prior to testing, they shall be stored in saturated limewater at $73.4 \pm 3^\circ\text{F}$ ($23 \pm 1.7^\circ\text{C}$). Drying of the surfaces of the beam shall be prevented between removal from the limewater and completion of testing. (Note 3)

Note 3 -Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9 Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance or Quality Control at Remote Sites:

- 9.1** Specimens prepared and stored at remote sites, which do not have facilities for controlling temperature with the tolerance of $73.4^{\circ}\pm 3^{\circ}\text{F}$ ($23\pm 1.7^{\circ}\text{C}$) shall be cured in accordance with the provisions of Section 9.2 except as modified by Section 9.3.
- 9.2** *Initial Curing at Remote Sites* – Specimens shall be cured in accordance with Section 8.
- 9.2.1** Specimens that will not be transported or are to be transported after 48 hours age may be cured without demolding provided that loss of moisture is prevented in accordance with section 8 until the time of transportation or testing.
- 9.3** *Standard Curing at Remote Sites* – Specimens to be stored at a remote site and shipped to a laboratory for test or to be tested at the remote site shall be cured in accordance with Sections 9.1, 9.2, and 9.2.1 until the time of shipment or test. Specimens shall not be exposed dripping or running water.
- 9.3.1** Beam specimens to be stored at remote sites shall be cured in accordance with Section 9, except for a minimum of 20 hours before testing, they shall be stored in saturated lime water at 60° to 80°F (16° to 27°C). Drying of the surfaces of the beam shall be prevented between removal from the limewater and completion of testing. (Note 4).

Note 4 – Curing of specimens at remote sites in accordance with Section 9 may yield significantly different results as compared to specimens cured in accordance with Section 8.2.

10 Curing for Form Removal Time or When a Structure May be Put into Service:

- 10.1** *Cylinders* – Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified moisture treatment. To meet these conditions, specimens made for the purpose of determining when a structure may be put in service shall be removed from the molds at the time of removal of formwork.
- 10.2** *Beams* – As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the side and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structural concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in limewater at $73.4 \pm 5^{\circ}\text{F}$ ($23 \pm 2.8^{\circ}\text{C}$) for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in Section 8.4.2 to guard against drying between time of removal from curing to testing.

11 Shipment to Laboratory:

- 11.1** Cylinders and beams shipped from the field to the laboratory for testing shall be packed in sturdy wooden boxes supplied by the Materials Bureau, surrounded by wet sawdust and protected from freezing during shipment. Upon receipt by the laboratory, cylinders shall be capped and immediately placed in the moist room. The shipper shall fill out Laboratory Form No. 93 and place

11 Shipment to Laboratory: (continued)

one copy in the plastic envelope supplied, to accompany the cylinder, mail one copy to the Materials Bureau, and retain one copy for the shipper's file.

- 11.2** Test specimens shall not be shipped from the field until at least three days after casting.
- 11.3** Retaining the cylinders on the project for three days will permit sufficient strength to develop to greatly reduce the possibility of latent damage from rough handling or exposure to low temperatures during shipping. Past cylinder failure investigations have produced considerable evidence that such latent damage may be a major factor in low-test cylinder strengths. This is particularly evident where cylinders have been removed from the molds and shipped the day after casting during periods of below freezing weather.
- 11.4** It is realized that, in some cases, retaining the cylinders on the project for three days may result in the first cylinder being tested later than the specified seven days. However, a late seven-day test is preferable to the possibility of damaging the entire set by shipping before adequate strength is developed. Every effort should be made, however, to comply with paragraph 8.3 above in order that the specimen will receive the 24-hour curing in the moist room in the Materials Bureau.

12 Preparation of Laboratory Form No. 93:

- 12.1** Form No. 93, which accompanies each cylinder, should be completed with extreme care, paying particular attention to the date when the cylinders were made. The mix design, water and air content, cement certification and the laboratory numbers of the aggregates being used should be checked to make certain they are correct and they should be changed whenever new project mixes, laboratory numbers or other information is available. Project numbers should be accurate and complete including unit numbers and the correct termini should be shown. Special attention is directed to MT-510, Field Numbering Concrete Cylinders.